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JC839 U.S. PTO
07/08/00

JC836 U.S. PTO
09/612649
07/08/00

DATE: 8 July 00 OUR REF 9915125(018)

HON. COMMISSIONER OF PATENTS AND TRADEMARKS
WASHINGTON, D.C. 20231

SIRS:

Attached is the following (PCT) application papers (x) spec. (x) claims. (x) formal drawing. (x) declaration, power of attorney, petition. ( ) certified copy. ( ) Rule 1.97/8 statement.

Enclosed are: Fee Calculation sheet,showing fee enclosed or in duplicate authorizes charge to Deposit Account; (XXX) Assignment and Cover Sheet, showing fee enclosed or in duplicate authorizes charge to the Deposit Account., and preliminary amendment.

Convention Priority is (X) is not ( ) asserted on Japan SN 11/254,102 filed 9/8/99

The certified copy(s) will be filed shortly (x).

( )This is a small entity/individual application. A certification to that effect is filed herewith( ) or will be filed shortly( ).

( )The following PCT documents are filed.( ) Transmittal letter. ( ) Request. ( ) International Search Report. ( )others.**

INVENTOR(S)- Tetsuji TSUKAMOTO

TITLE - Spin excitation method and apparatus and magnetic resonance imaging apparatus

(see above * or **)

MOONRAY KOJIMA
BOX 627
WILLIAMSTOWN, MASS 01267

Respectfully,

M. KOJIMA -Tel (413)458-2880

I hereby certify that the correspondence upon which this notice is placed is being deposited with the US Postal Service as EXPRESS first class mail in an envelope addressed to the Commissioner of Patents, Washington, D.C. 20231, on the date set forth below.
MOONRAY KOJIMA, ATTORNEY. (signed) _____ Date 7/8/00

EXPRESS MAIL NO. EJ845944069US MAILED 7/8/00

JC839 U.S. PTO
07/08/00

DOCKET NO. 9915125(018)
IN THE US PATENT OFFICE

EXAMINER -

GROUP -

SN -

FILED - concurrently herewith

BY - Tsukamoto

SIRS:

FEE CALCULATION

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MOONRAY KOJIMA, ATTORNEY

DATE: 7/8/00

Document on which fee is calculated:

[x] Application [ ] Amendment and preliminary amendment

Entity Status: [x] Non-small entity

[ ] Small Entity; [ ] cert. filed herewith [ ] Cert. filed priorly

APPLICATION

	Basic Fee			$ 690.00
(4)	Main claims (-3)	1 x $ 78	=	$ 78.00
(16)	Total Claims (-20)	0 X $	=	$ 0
	Multiple Dep. [ ] Yes [x] No			$ 0
			TOTAL	$ 768.00

AMENDMENT

	After Amend.		Highst Prior				
Basic Fee							$
Main claims (-3)		(-)		=		X $	= $
Total Claims (-20)		(-)		=		X $	= $
Multiple Dep. 1st time [ ] Yes [ ] No.							$
						DEFICIENCY	$

FEE DUE $ 768.00 [ ] Enclosed herewith by check

[x] Charge to DA 11-1500, duplicate attached.

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DATE: 7/8/02

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PRELIMINARY AMENDMENT

BY - Tsukamoto

SIRS:

Kindly amend the above as follows:

SPECIFICATION

Page 3, line 9, change "Figure 2 illustrates" to -- Figures 2(A) - 2(E) illustrate---

Page 3, line 15, change "6-8" to -- 6(A)- 6(C), 7(A)-7(D) and 8(A)- 8(D) --

, lines 15,16 - change "Figure 2" to -- Figures 2(A) -2(E)--

Page 6, line 20, change "Figure 2" to -- Figures 2(A) - 2(E) --

, line 22, change "(1)" to -- Figure 2(A) --

, line 23, change "(2), (3), (4) and (5)" to -- Figures 2(B), 2(C), 2(D) and 2(E) --

Page 9, line 29, change "Figure 7" to -- Figures 7(A) - 7(D)--

, line 30, change "(C)" to -- of Figure 7(C)--

Page 10, line 1, change '(d)" to -- of Figure 7(D)--

, line 18, change "Figure 8" to -- Figures 8(A)-8(D)--

, line 20, before "(a) insert -- Figure 8--

, before (c)" insert -- Figure 8 --

CLAIMS

Claim 16, cancel without prejudice and substitute therefor claim 17.

Add the following claim ---

17. A magnetic resonace imaging method comprising the steps of:

generating a static magnetic field in a space containing an object to be imaged;

generating a gradient magnetic field in said space;

transmitting an RF excitation signal to said space;

receiving a magnetic resonance signal from said space; and

producing an image based on said received magnetic resonance signal; wherein said transmission is performed by a spin excitation method comprising the steps of:

predicting a specific absorption ratio of the object to be imaged in executing a pulse sequence; and

adjusting at least one among a number of pulses, pulse waveform and pulse width of said RF pulses in said pulse sequence so that said specific absortion ratio value falls with a predetermined limit.

REMARKS

The amendments to the spec were made to conform the drawing designation to US practice. Also, claim 16 has been amended (and rewritten in clean copy as claim 17) to clarify the terms thereof

Entry is respectfully solicited.

Respectfully,

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8 July 00

SPIN EXCITATION METHOD AND APPARATUS AND MAGNETIC RESONANCE IMAGING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to a spin excitation method and apparatus and a magnetic resonance imaging apparatus, and more particularly to a spin excitation method and apparatus which excite spins within an object to be imaged by a pulse sequence containing RF (radio frequency) pulses, and a magnetic resonance imaging apparatus employing such a spin excitation apparatus.

When spins within an object to be imaged are RF-excited in a magnetic resonance imaging apparatus, the apparatus suppresses the SAR (specific absorption rate) by the RF excitation below a predetermined standard value to ensure safety of the object to be imaged. For this purpose, each time scan conditions are specified, the magnetic resonance imaging apparatus predicts the SAR in performing imaging under the conditions, and if the predicted SAR exceeds the standard value, the scan conditions are modified. The modification of the scan conditions is conducted automatically or by prompting an operator to re-specify the scan conditions.

Since the SAR is approximately proportional to the square of the frequency of the RF excitation signals, if the magnetic resonance imaging apparatus employs a high-strength magnetic field on, for example, the order of 3 T (Tesla) as a static magnetic field, the SAR tends to deviate from the limit due to an increase of frequency of the RF excitation signals, thereby increasing the occurrence of the scan condition modification. While the scan condition modification for reducing the SAR is usually carried out by reducing the number of slices scanned during 1TR in multislice scanning, reducing the number of slices lowers the imaging efficiency.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a spin excitation method and apparatus for performing imaging with good efficiency while keeping within an SAR limit, and a magnetic resonance imaging apparatus employing such a spin excitation apparatus.

In accordance with a first aspect of the invention, there is provided a spin excitation method for exciting spins within an object to be imaged by a pulse sequence containing RF pulses, the method comprising the steps of: predicting an SAR of the object to be imaged in executing the pulse sequence; and adjusting at least one among the number of pulses, pulse waveform and pulse width of the RF pulses in the pulse sequence so that the predicted SAR value falls within a predetermined limit.

In accordance with a second aspect of the invention, there is provided a spin excitation apparatus for exciting spins within an object to be imaged by a pulse sequence containing RF pulses, the apparatus comprising: SAR prediction means for predicting an SAR of the object to be imaged in executing the pulse sequence; and RF pulse adjusting means for adjusting at least one among the number of pulses, pulse waveform and pulse width of the RF pulses in the pulse sequence so that the predicted SAR value falls within a predetermined limit.

(EFFECT)

According to the present invention, at least one among the number of pulses, pulse waveform and pulse width of RF pulses in a pulse sequence is adjusted so that a predicted SAR value falls within a predetermined limit. Since the number of slices during 1TR is therefore not reduced, lowering of imaging efficiency is prevented.

Therefore, the present invention can provide a spin excitation method and apparatus for performing imaging with good efficiency while keeping within an SAR limit, and a magnetic resonance imaging apparatus

employing such a spin excitation apparatus.

Further objects and advantages of the present invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of an apparatus in accordance with an embodiment of the present invention.

Figure 2 illustrates an exemplary pulse sequence executed by the apparatus shown in Figure 1.

Figure 3 illustrates the conception of multislice.

Figure 4 is a time chart of multislice scanning.

Figure 5 is a block diagram illustrating the function of the data processing section in the apparatus shown in Figure 1.

Figures 6 — 8 illustrate part of the pulse sequence shown in Figure 2.

Figure 9 is a flow chart of the operation of the apparatus shown in Figure 1.

Figure 10 is a flow chart illustrating part of the flow chart shown in Figure 9.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. Figure 1 shows a block diagram of a magnetic resonance imaging apparatus, which is an

embodiment of the present invention. The configuration of the apparatus represents an embodiment of the apparatus in accordance with the present invention.

As shown in Figure 1, the present apparatus has a magnet system 100. The magnet system 100 has a main magnetic field coil section 102, a gradient coil section 106 and an RF (radio frequency) coil section 108. These coil sections have a generally cylindrical outer shape and are concentrically disposed. An object to be imaged 300 is rested on a cradle 500 and carried into and out of the internal space of the magnet system 100 by carrier means (not shown).

The main magnetic field coil section 102 generates a static magnetic field in the internal space of the magnet system 100. The main magnetic field coil section 102 is an embodiment of the static magnetic field generating means of the present invention. The direction of the static magnetic field is generally in parallel with the direction of the body axis of the object to be imaged 300, i.e., a "horizontal" magnetic field is generated. The main magnetic field coil section 102 is made using a superconductive coil, for example. It will be easily recognized that the main magnetic field coil section 102 is not limited to a superconductive coil, but may be made using a normal conductive coil or the like.

The gradient coil section 106 generates gradient magnetic fields for imparting gradients to the static magnet field strength. The gradient magnetic fields to be generated include a slice gradient magnetic field, a readout gradient magnetic field and a phase encoding gradient magnetic field. The gradient coil section 106 has three gradient coils (not shown) corresponding to these three gradient magnetic fields.

The RF coil section 108 generates a high frequency magnetic field for exciting spins within the object to be imaged 300. The generation of the high frequency magnetic field will be referred to as transmission of an RF excitation signal hereinbelow. The RF coil section 108 also receives an electromagnetic wave generated by the excited spins, i.e., a magnetic resonance signal.

The gradient coil section 106 is connected with a gradient driving section 130 for supplying driving signals to the gradient coil section 106 to generate the gradient magnetic fields. A gradient magnetic field will sometimes be referred to simply as a gradient hereinbelow. A portion consisting of the gradient coil section 106 and the gradient driving section 130 is an embodiment of the gradient magnetic field generating means of the present invention. The gradient driving section 130 has three driving circuits (not shown) corresponding to the three gradient coils in the gradient coil section 106.

The RF coil section 108 is connected with an RF driving section 140. A portion consisting of the RF coil section 108 and the RF driving section 140 is an embodiment of the transmit means of the present invention. The RF driving section 140 supplies driving signals to the RF coil section 108 to transmit the RF excitation signals, thereby exciting the spins within the object to be imaged 300.

The RF coil section 108 is also connected with a data acquisition section 150. A portion consisting of the receive coil section 110 and the data acquisition section 150 is an embodiment of the receive means of the present invention. The data acquisition section 150 gathers signals received by the RF coil section 108 and acquires the signals as digital data.

The gradient driving section 130, RF driving section 140 and data acquisition section 150 are connected with a control section 160 for controlling these sections 130 — 150.

The output of the data acquisition section 150 is connected to a data processing section 170. The data processing section 170 stores data gathered from the data acquisition section 150 in a memory (not shown). Thus, a data space is formed in the memory, which constitutes a two-dimensional Fourier space, i.e., a "k-space". The data processing section 170 performs a two-dimensional inverse Fourier transformation on the data in the two-dimensional Fourier space to reconstruct an image of the object to be imaged 300. The data processing section 170 is an embodiment of the image producing means of the present invention.

The data processing section 170 is connected to the control section 160. The data processing section 170 is above the control section 160 and controls the section 160. A portion consisting of the data acquisition section 150, control section 160, RF driving section 140 and RF coil section 108 is an embodiment of the spin excitation apparatus of the present invention. The configuration of the excitation apparatus represents an embodiment of the spin excitation apparatus in accordance with the present invention, and the operation of the excitation apparatus represents an embodiment of the spin excitation method in accordance with the present invention.

The data processing section 170 is connected with a display section 180 that displays the reconstructed image and several kinds of information output from the data processing section 170, and an operating section 190 that is operated by a human operator and inputs several commands, information and so forth to the data processing section 170.

The operation of the present apparatus in magnetic resonance imaging will now be described. The operation described hereinbelow proceeds under the control of the control section 160. The magnetic resonance imaging employs a pulse sequence schematically and exemplarily shown in Figure 2. The illustrated pulse sequence is one in accordance with a fast spin echo (FSE) technique.

Specifically, (1) is a sequence of a 90° pulse and 180° pulses for RF excitation of the FSE, and (2), (3), (4) and (5) are sequences of a slice gradient Gs, a readout gradient Gr, a phase encoding gradient Gp and spin echoes MR of the FSE, respectively. It should be noted that the 90° and 180° pulses and the spin echoes MR are represented by their respective center signals. The pulse sequence proceeds from the left to the right along a time axis t.

As shown, 90° excitation of the spins is done by the 90° pulse. At the same time, the slice gradient Gs is applied to achieve selective excitation of a predefined slice. After the 90° excitation, a first 180° pulse is applied. Again, the slice gradient Gs is applied to achieve selective

excitation of the same slice.

After the first 180° application, a 180° pulse, the slice gradient Gs, readout gradient Gr and phase encoding gradient Gp are applied at respective timings. The readout gradient Gr is applied each time the 180° pulse inverts the spins, performing readout of a spin echo.

The phase encoding gradient Gp is applied before and after each readout gradient Gr. The phase encoding gradient applied before the readout gradient Gr phase-encodes the spins, and that applied after the readout gradient Gr restores the phase encoding of the spins to zero. Thus, a plurality of spin echoes MR are sequentially generated.

A plurality of spin echoes are thus generated for one 90° excitation. The plurality of spin echoes have different phase encodings. The number of echoes here is six, but this is only for convenience of illustration. It is not limited to six but may be any appropriate number.

These spin echoes are collected as digital data in the k-space into the memory of the data processing section 170. Since the phase encodings are individually different, the echo data form separate trajectories in the k-space.

The above operation is repeated in a cycle of TR (repetition time) taking the spin relaxation time into account, to collect echo data for a separate trajectory each time, and echo data are obtained for all the trajectories by a predetermined number of times of repetition.

While waiting for spin relaxation of one slice, similar scanning of other slices are sequentially performed to achieve "multislice" scanning. Specifically, as exemplarily shown in Figure 3, a slice s1 is first scanned, a slice s2 is next scanned, and thereafter, slices s3, s4, s5 are sequentially scanned. Around the time when scanning of the slice s5 is completed, the time TR has expired. Then, similar scanning is repeated again from the slice s1. A time chart of such multiscan is shown in Figure 4.

The data processing section 170 performs a two-dimensional

inverse Fourier transformation on the k-space data for each slice, and reconstructs a multislice tomographic image of the object to be imaged 300. The reconstructed image is saved in the memory, and displayed on the display section 180 as a visual image.

In performing such imaging, since RF excitation, specifically 180° excitation, is used many times, the SAR of the object to be imaged 300 is increased. The SAR markedly increases especially under a static magnetic field strength as high as 3 T.

Then, before executing the pulse sequence, the data processing section 170 calculates a predicted SAR value in executing the pulse sequence, compares the predicted value with a standard SAR value predetermined in view of safety, and if the predicted value exceeds the standard, reduces the SAR to a value conformable to the standard by adjusting the RF pulses.

Figure 5 shows a block diagram of the data processing section 170 relating to RF pulse adjustment. As shown, the data processing section 170 has an imaging condition memory unit 702, an SAR prediction unit 704 and a pulse adjustment unit 706. The imaging condition memory unit 702 is implemented by the memory of the data processing section 170. The SAR prediction unit 704 and pulse adjustment unit 706 are implemented by a computer program or the like on the data processing section 170.

The SAR prediction unit 704 is an embodiment of the SAR prediction means of the present invention. The pulse adjustment unit 706 is an embodiment of the RF pulse adjustment means of the present invention.

The SAR prediction unit 704 reads imaging conditions, i.e., a pulse sequence to be employed in imaging, out of the imaging condition memory unit 702, and predicts an SAR when scanning is performed with the pulse sequence. The prediction of the SAR is performed based on a sequence of RF pulses in the pulse sequence.

Since an instantaneous value of an RF pulse A(t) and the SAR have a relationship as follows:

$$SAR \propto \int |A(t)|^2 dt , \qquad (1)$$

the SAR prediction unit 704 first calculates a value of the right side of Eq. (1) for the RF pulse sequence. Specifically, as shown in Figure 6(b), a value of the right side of Eq. (1) is calculated for a series of 90° and 180° pulses contained in the RF pulse sequence.

The 90° and 180° pulses have a waveform as exemplarily indicated by Figure 6(c) in default. A pulse that has such a waveform is called as an SLR (Shinnar-Le Roux) pulse. It should be noted that the area of the 90° pulse is half the area of the 180° pulse.

The SAR prediction unit 704 then checks how many normal RF pulses the calculated value of the above equation corresponds to. The value of the right side of Eq. (1) is known for a normal RF pulse, and an SAR corresponding thereto is also known from measurements. That is, for the normal RF pulse, the proportionality constant in Eq. (1) is known from measurements.

Therefore, the predicted SAR value in executing a pulse sequence can be obtained by converting the value of the right side of Eq. (1) for the RF pulses contained in the pulse sequence into the number of normal RF pulses.

The predicted SAR value thus obtained is input to the pulse adjustment unit 706. The pulse adjustment unit 706 checks the SAR predicted value based on a predetermined safety standard value. For example, the safety standard value of SAR is standardized as 3 W/kg or lower for a head.

If the predicted SAR value exceeds the safety standard value, the pulse adjustment unit 706 adjusts the RF pulses. As exemplarily shown in Figure 7, the adjustment of RF pulses is achieved by, for example, modifying an original SLR pulse waveform (c) into a sinc pulse waveform

(d). However, since the flip angle of spins and an RF pulse have a relationship as follows:

$$FlipAngle \propto \int A(t)dt, \qquad (2)$$

when the waveform is changed, the value of the right side of Eq. (2), i.e., the area of a pulse, should be prevented from changing in order to maintain the same flip angle. A sinc pulse waveform satisfying such a condition generally has a smaller value of the right side of Eq. (1) than the SLR pulse waveform. Accordingly, the pulse sequence after waveform modification has a reduced SAR. Although such RF pulse adjustment is performed principally on 180° pulses, it will be easily recognized that the RF pulse adjustment may be performed on pulses including a 90° pulse.

The modification on the RF pulses for reducing the SAR is not limited to modification to a sinc pulse waveform, but a waveform may be employed which is obtained by filtering an SLR pulse waveform by, for example, a Hamming filter, Hanning filter or any other appropriate filters. Also in this case, it is possible to reduce the SAR under the condition of waveform area invariance.

Alternatively, as shown in Figure 8, the SLR waveform may be left unchanged, while its pulse width may be widened from the state shown in (a) to that shown in (c). Under the condition of area invariance, the amplitude is reduced by widening the pulse width, thereby allowing the SAR to be reduced. In this case, the readout gradient should be adjusted concurrently with the increase of the pulse width of the 180° pulse. Although omitted from the drawing, the same applies to the slice gradient. Such adjustment is also included in the function of the pulse adjustment unit 706.

To reduce the SAR, the number of the 180° pulses may be reduced. This reduces the number of times of 180° excitation, hence reducing the SAR. Moreover, any one of the foregoing techniques may be solely employed, or a combination of the techniques may be employed as needed.

Then, new imaging conditions employing the RF pulses thus adjusted are stored in the imaging condition memory unit 702. The SAR prediction unit 704 again performs SAR prediction on the modified imaging conditions. If the SAR does not meet the standard, the RF pulses or the like are adjusted at the pulse adjustment unit 706. The pulse sequence is modified so that the predicted SAR value meets the standard through repeating the process.

The operation of the present apparatus will now be described. Figure 9 shows a flow chart of the operation. As shown, imaging conditions are input at Step 902. Specifically, an user of the present apparatus inputs imaging conditions interactively using the operating section 190 and display section 180.

A detailed flow chart of the imaging condition input is shown in Figure 10. As shown, basic parameters relevant to imaging are input at Step 912, including, for example, the type of the pulse sequence, TR, TE (echo time), the number of echoes, FOV (field of view), the image matrix size, etc. Next, the number of slices is input at Step 914.

After inputting these parameters, a predicted SAR value is calculated at Step 916. The calculation of the predicted SAR value is performed in one of the ways described above by the SAR prediction unit 704 in the data processing section 170.

At Step 918, it is checked whether the predicted SAR value thus calculated exceeds the standard SAR value. If the predicted value is larger than the standard SAR value, the parameters of RF pulses and the like are modified at Step 920. This process is performed in a manner as described above by the pulse adjustment unit 706 in the data processing section 170.

In modifying the parameters, a plurality of options for the RF pulse waveform, including, for example, a high-SAR type, mid-SAR type, low-SAR type and the like, are preferably displayed on the display section 180 for the user to select, because this can allow the user's intention to be

suitably incorporated.

After modification of the parameters, the predicted SAR value is re-calculated at Step 916, and again checked against the standard value at Step 918. The foregoing process is repeated so long as the predicted SAR value exceeds the standard value.

When the predicted SAR value becomes lower than the standard value or when it is below the standard value from the beginning, the user inputs the remaining parameters at Step 922, including, for example, the site to be imaged and the slice direction (axial, sagittal or coronal).

After inputting these imaging conditions, scanning is performed at Step 904 in the flow chart of Figure 9. By adjusting the imaging conditions as above, the scanning is achieved within the SAR safety standard. Yet, imaging is performed with good efficiency because the number of slices is maintained as initially specified by the user.

Next, at Step 906, an image is reconstructed based on the scan data, and is displayed by the display section 180 and saved in the memory at Step 908.

Although the present invention has been described with reference to imaging by an FSE pulse sequence, the imaging is not limited to the FSE technique. The present invention is also applicable to pulse sequences according to the spin echo (SE) technique and the inversion recovery (IR) technique, and other pulse sequences that frequently use RF excitation. The same effect can be obtained in these cases.

Many widely different embodiments of the invention may be configured without departing from the spirit and the scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments described in the specification, except as defined in the appended claims.

CLAIMS:

1. A spin excitation method for exciting spins within an object to be imaged by a pulse sequence containing RF pulses, said method comprising the steps of:

predicting a specific absorption ratio (SAR) of the object to be imaged in executing said pulse sequence; and

adjusting at least one among the number of pulses, pulse waveform and pulse width of said radio frequency (RF) pulses in said pulse sequence so that said predicted SAR value falls within a predetermined limit.

2. The spin excitation method as defined in claim 1, wherein said RF pulses to be adjusted are 180° pulses.

3. The spin excitation method as defined in claim 1, wherein the adjustment of the pulse waveform of said RF pulses is modification from a Shinnar-Le Roux (SLR) pulse waveform to a sinc pulse waveform.

4. The spin excitation method as defined in claim 1, wherein the adjustment of the pulse waveform of said RF pulses is modification from an SLR pulse waveform to a waveform obtained by filtering said SLR pulse waveform.

5. The spin excitation method as defined in claim 1, wherein said filtering employs a Hamming filter.

Page 13 of 16

6. A spin excitation apparatus for exciting spins within an object to be imaged by a pulse sequence containing RF pulses, said apparatus comprising:

SAR prediction means for predicting an SAR of the object to be imaged in executing said pulse sequence; and

RF pulse adjusting means for adjusting at least one among the number of pulses, pulse waveform and pulse width of said RF pulses in said pulse sequence so that said predicted SAR value falls within a predetermined limit.

7. The spin excitation apparatus as defined in claim 6, wherein said RF pulses to be adjusted are 180° pulses.

8. The spin excitation apparatus as defined in claim 6, wherein the adjustment of the pulse waveform of said RF pulses is modification from an SLR pulse waveform to a sinc pulse waveform.

9. The spin excitation apparatus as defined in claim 6, wherein the adjustment of the pulse waveform of said RF pulses is modification from an SLR pulse waveform to a waveform obtained by filtering said SLR pulse waveform.

10. The spin excitation apparatus as defined in claim 6, wherein said filtering employs a Hamming filter.

11. A magnetic resonance imaging apparatus having:

static magnetic field generating means for generating a static magnetic field in a space containing an object to be imaged;

gradient magnetic field generating means for generating a gradient magnetic field in said space;

transmit means for transmitting an RF excitation signal to said space;

receive means for receiving a magnetic resonance signal from said space; and

image producing means for producing an image based on said received magnetic resonance signal,

wherein the spin excitation apparatus as defined in claim 6 is employed as said transmit means.

12. The magnetic resonance imaging apparatus as defined in claim 11, wherein said RF pulses to be adjusted are 180° pulses.

13. The magnetic resonance imaging apparatus as defined in claim 11, wherein the adjustment of the pulse waveform of said RF pulses is modification from an SLR pulse waveform to a sinc pulse waveform.

14. The magnetic resonance imaging apparatus as defined in claim 11, wherein the adjustment of the pulse waveform of said RF pulses is modification from an SLR pulse waveform to a waveform obtained by filtering said SLR pulse waveform.

15. The magnetic resonance imaging apparatus as defined in

claim 11, wherein said filtering employs a Hamming filter.

16. A magnetic resonance imaging method comprising the steps of generating a static magnetic field in a space containing an object to be imaged, generating a gradient magnetic field in said space, transmitting an RF excitation signal to said space, receiving a magnetic resonance signal from said space, and producing an image based on said received magnetic resonance signal, wherein said transmission is performed by the spin excitation method as defined in claim 1.

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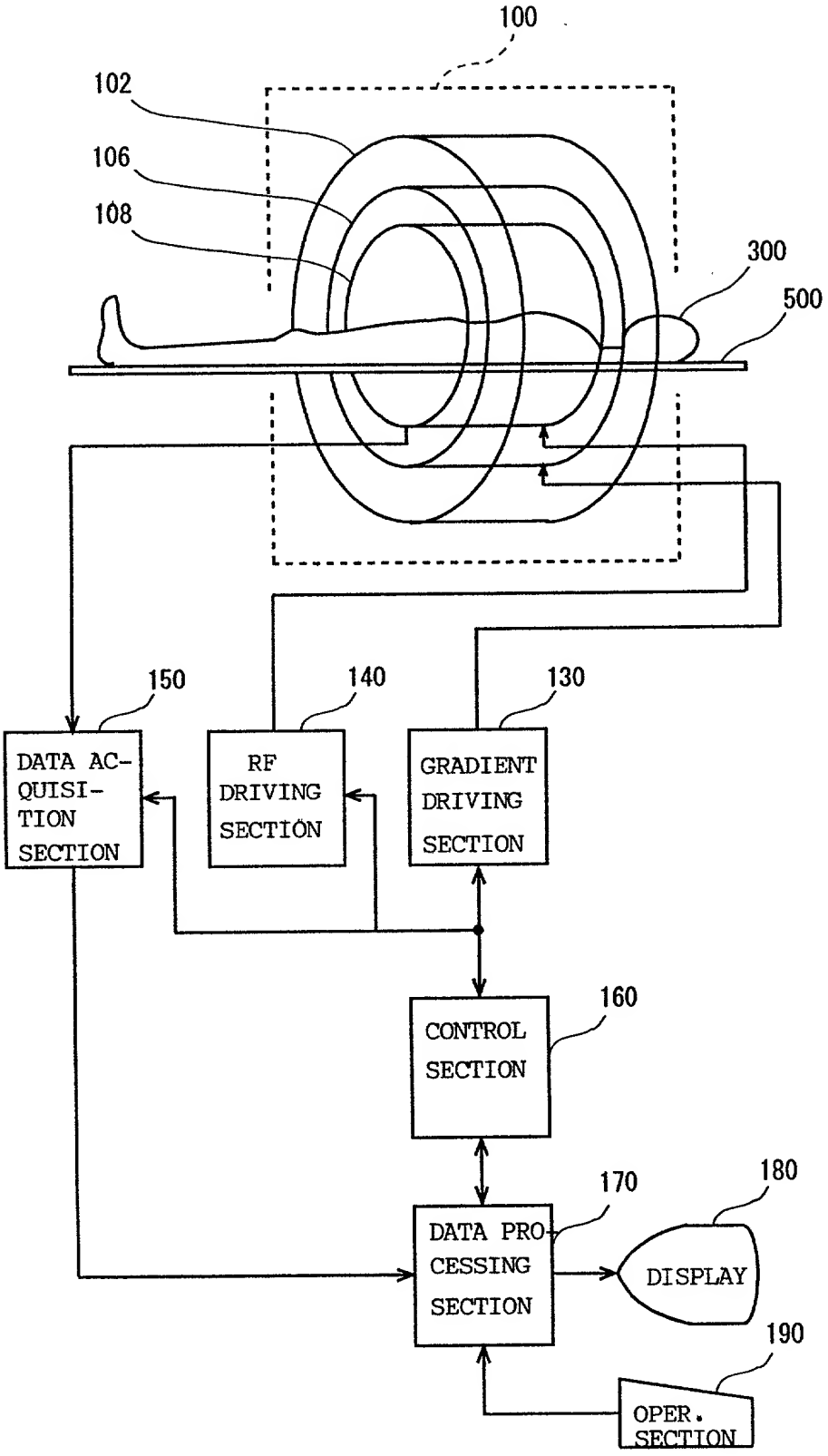
SPIN EXCITATION METHOD AND APPARATUS AND MAGNETIC RESONANCE IMAGING APPARATUS

ABSTRACT OF THE DISCLOSURE

In order to provide a spin excitation method and apparatus for performing imaging with good efficiency while keeping within an SAR limit, and a magnetic resonance imaging apparatus employing such a spin excitation apparatus, an SAR of an object to be imaged in executing a pulse sequence is predicted (704); and at least one among the number of pulses, pulse waveform and pulse width of the RF pulses in the pulse sequence is adjusted (706) so that the predicted SAR value falls within a predetermined limit.

Docket #: 16NM99125

FIG. 1


100
102
106
108
300
500
150
140
130
DATA AC-
QUISI-
TION
SECTION
RF
DRIVING
SECTION
GRADIENT
DRIVING
SECTION
160
CONTROL
SECTION
170
180
DATA PRO-
CESSING
SECTION
DISPLAY
190
OPER.
SECTION

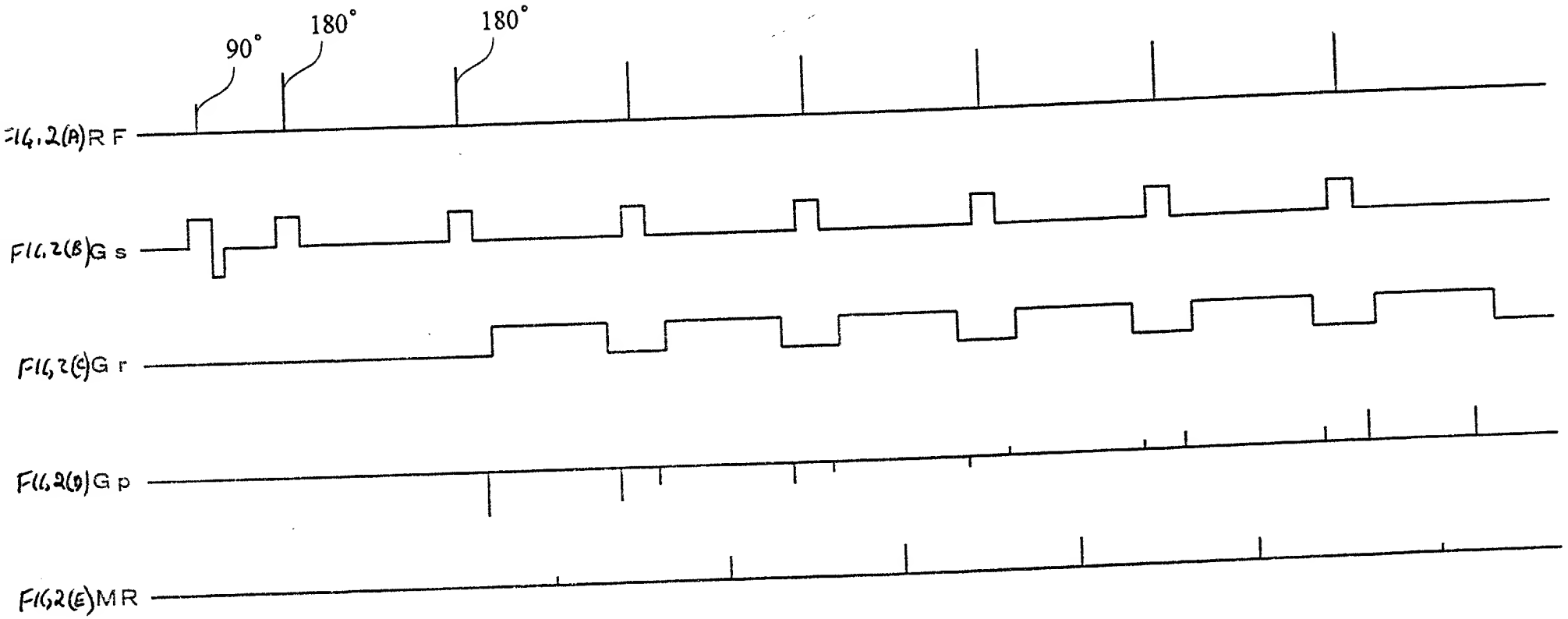

90°
180°
180°
FIG.2(A)RF
FIG.2(B)Gs
FIG.2(C)Gr
FIG.2(D)Gp
FIG2(E)MR

FIG. 3

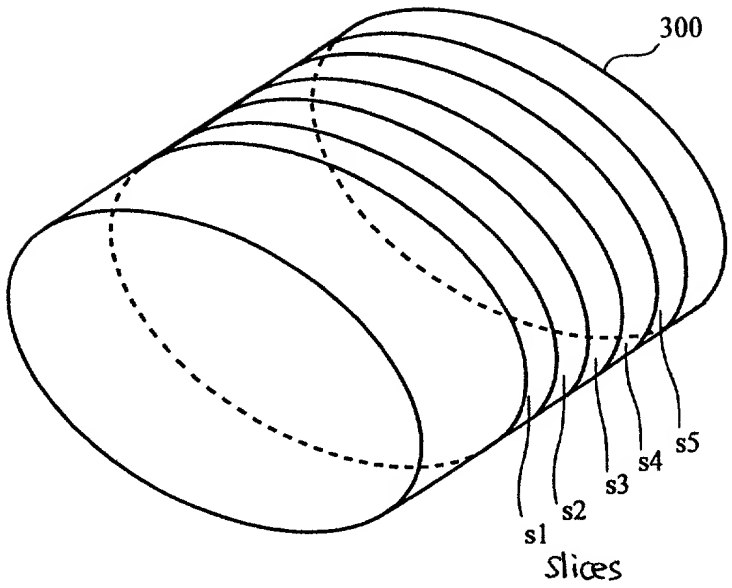
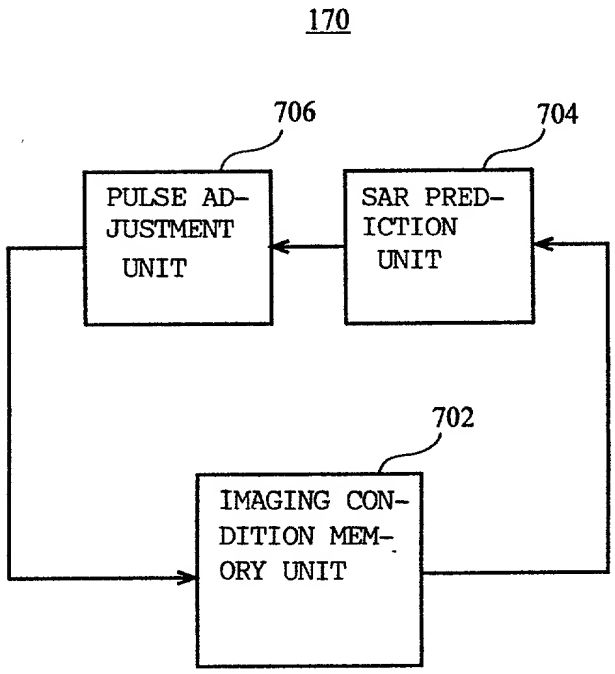

300
s1
s2
s3
s4
s5
Slices

FIG. 5


170
706
704
PULSE AD-
JUSTMENT
UNIT
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ICTION
UNIT
702
IMAGING CON-
DITION MEM-
ORY UNIT

FIG. 4

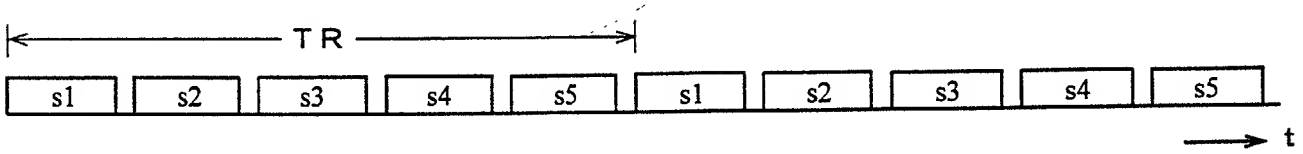


FIG. 6(a)

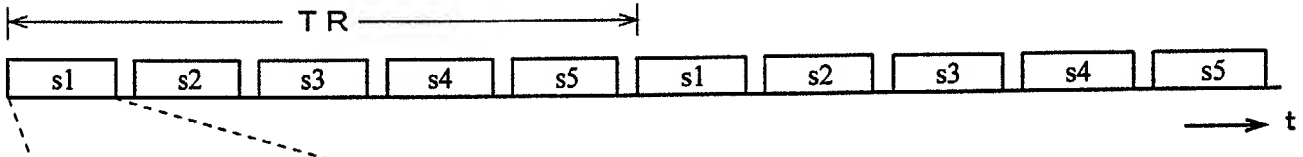


FIG. 6(b)

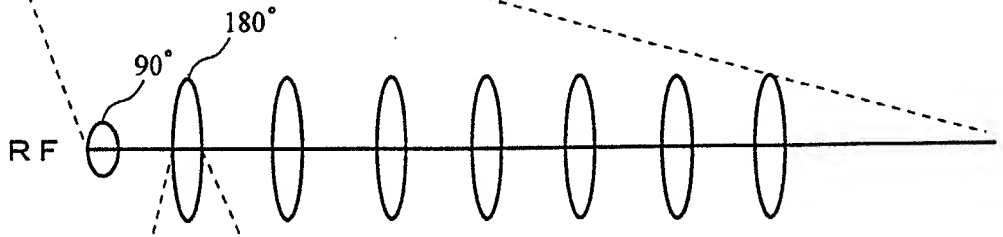


FIG. 6(c)

00802.0" 6h92T960

FIG. 7 (a)

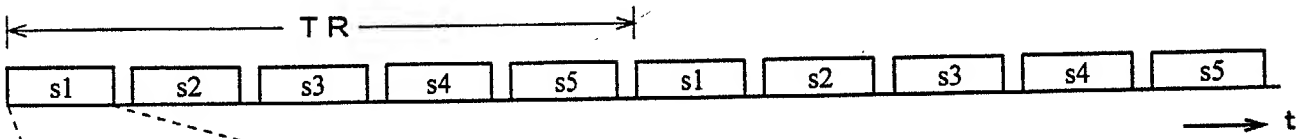


FIG. 7 (b)

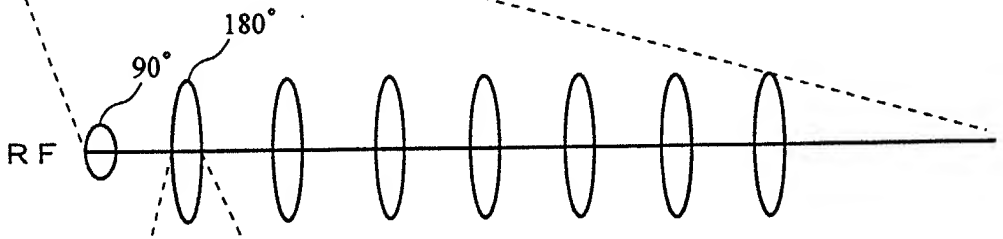


FIG. 7 (c)

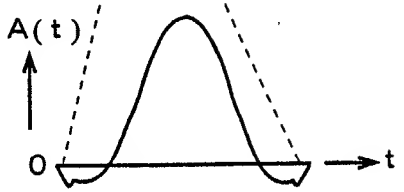
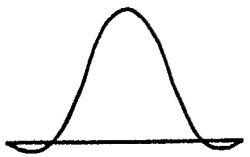


FIG. 7 (d)



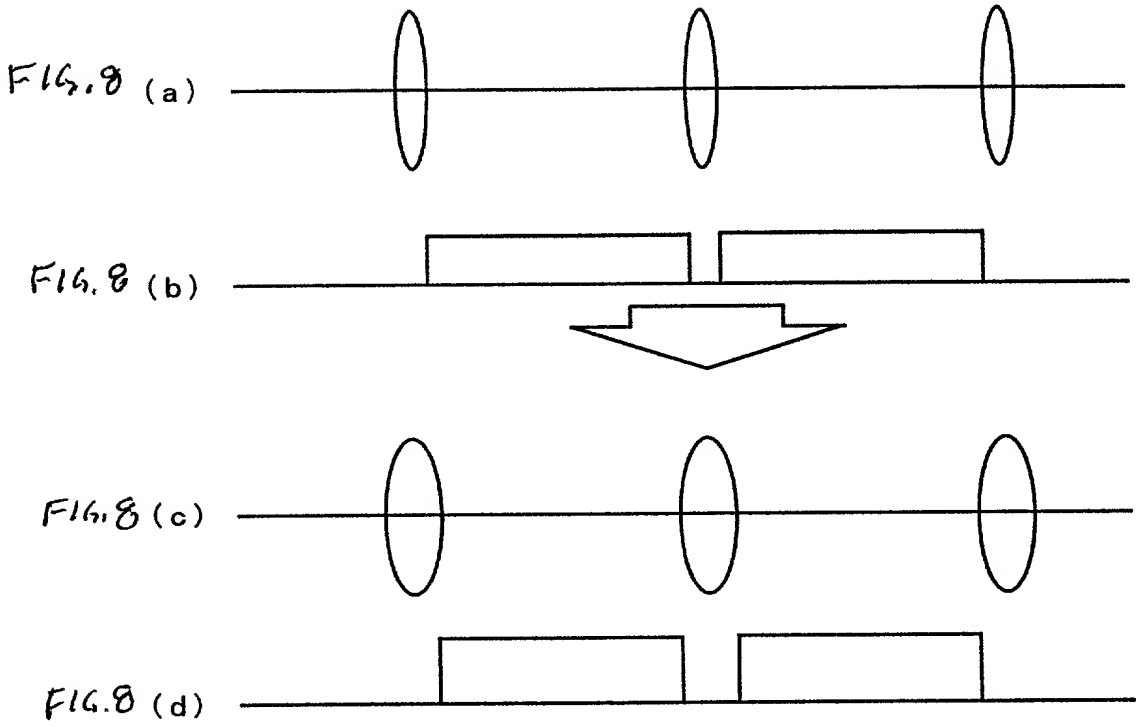


FIG. 8 (a)
FIG. 8 (b)
FIG. 8 (c)
FIG. 8 (d)

FIG. 9

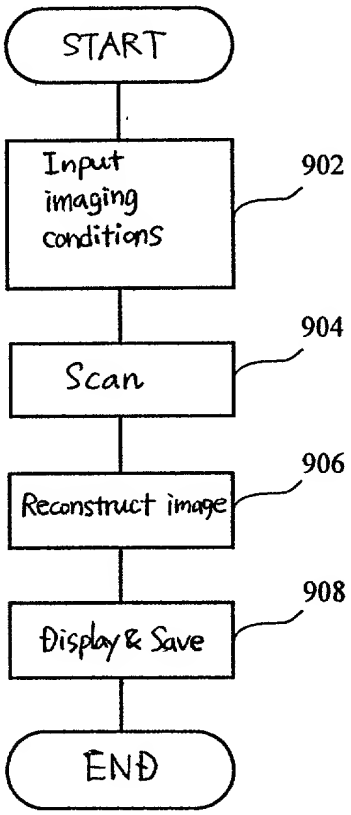
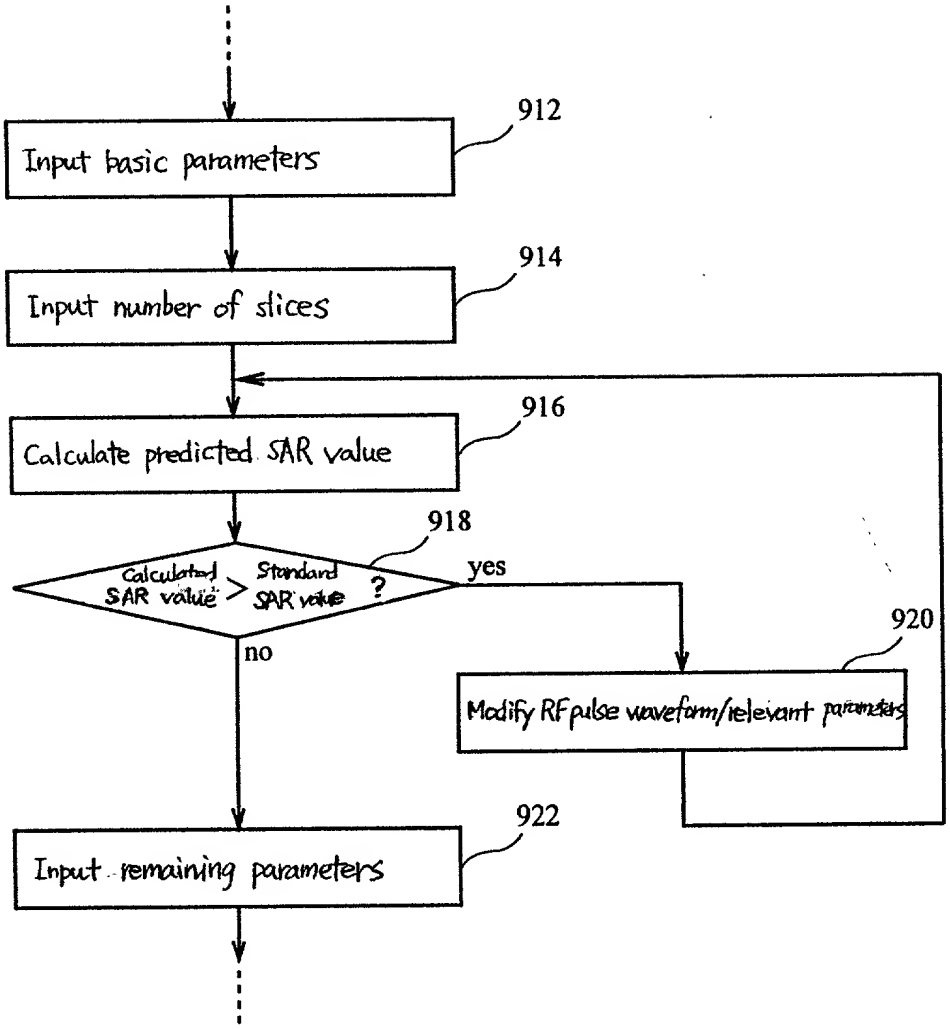

START
Input imaging conditions
902
Scan
904
Reconstruct image
906
Display & Save
908
END

FIG.10


Input basic parameters
912
Input number of slices
914
Calculate predicted SAR value
916
Calculated SAR value > Standard SAR value ?
918
yes
no
Modify RF pulse waveform/relevant parameters
920
Input remaining parameters
922

P-1A (6/95)

DECLARATION FOR PATENT APPLICATION

Docket Number (optional) 16NM99125

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is clamed and for which a patent is sought on the invention entitled SPIN EXCITATION METHOD AND APPARATUS AND MAGNETIC RESONANCE IMAGING APPARATUS, the specification of which is attached hereto unless the following box is checked:

☐ was filed on _____ as United States Application Number or PCT International Application Number _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Claimed
11-254102	JAPAN	8/9/99	☒ Yes ☐ No
(Number)	(Country)	(Day /Month/Year Filed)	
_____	_____	_____	☐ Yes ☐ No
(Number)	(Country)	(Day /Month/Year Filed)	

☐ I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

_____ _____
(Application Number) (Filing Date)

_____ _____
(Application Number) (Filing Date)

☐ I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

_____	_____	_____
(Application Number)	(Filing Date)	(Status ... patented, pending, abandoned)
_____	_____	_____
(Application Number)	(Filing Date)	(Status ... patented, pending, abandoned)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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WILLIAMSTOWN, MASS 01267

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor (given name, family name) Tetsuji Tsukamoto

Inventor's signature Tetsuji Tsukamoto Date June 29, 2000

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Full name of sole or second inventor (given name, family name) _____

Inventor's signature _____ Date _____

Residence _____ Citizenship _____

Post Office Address _____